**Robinson, Mark (MarkRobinson)**

**To:** Carla Fritz
**Subject:** RE: TEL Investigation
**Attachments:** Richmond 1 Lead Line Evaluation.pdf

Hi Carla,
Here is the entire document in pdf form.
Mark

*Mark W. Robinson*
*Safety Team Lead*
*Chevron Richmond Refinery*
*Safety (noun): Freedom from Danger*
*(510) 242-2233*

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**From:** Carla Fritz [mailto:CFritz@dir.ca.gov]
**Sent:** Wednesday, September 24, 2008 7:25 AM
**To:** Robinson, Mark (MarkRobinson)
**Subject:** RE: TEL Investigation

Thanks, Mark. Were you going to mail/email the attachments? Thanks.

*Carla Fritz*
No. CA Process Safety Management
(925) 602-5779
(925) 602-2668 (fax)

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**From:** Robinson, Mark (MarkRobinson) [mailto:MarkRobinson@chevron.com]
**Sent:** Tuesday, September 23, 2008 4:18 PM
**To:** Carla Fritz
**Subject:** RE: TEL Investigation

Carla,
Sorry for the delay in getting back to you. The line was taken out of service on 8/20/2008 when we realized that we had an outstanding inspection recommendation that had not been addressed for some time. The decision was made to lock out the line and not use it again until a reinspection could be made. The line was walked on 8/20 and 3 areas were clamp repaired on 8/25. After this work was completed the line was determined fit for continued service until its scheduled replacement in February 2009 as part of the new Avgas project. The line was recommissioned on 8/28 in order to make the next scheduled leaded gasoline tank blend.

This line is used intermittently, only when a leaded gasoline blend is required. Normally this would be for about six hours every 3 to 4 weeks.
I hope this answers your questions.
Mark

*Mark W. Robinson*
*Safety Team Lead*
*Chevron Richmond Refinery*

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**From:** Carla Fritz [mailto:CFritz@dir.ca.gov]
**Sent:** Friday, September 19, 2008 9:21 AM
**To:** Robinson, Mark (MarkRobinson)
**Subject:** TEL Investigation

Good morning, Mark. As we discussed at the Safety Summit, please do put those attachments in the mail pursuant to the FFS evaluations - no cover sheets required. A question relative to Tery's memo of 09/12/08: Mr. Bosi's report, 3rd ¶, states "The Plant advised that the #1 Lead Line was shutdown , and would not return to service prior to completion of qualified welded and/or mechanical clamp (encapsulation) repairs." When was the line shut down? If clamps are contemplated, when and how many will be installed? Thanks in advance for the courtesy of a reply.

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Richmond, California
September 12, 2008

**Richmond Refinery – Operating Integrity Assessment of the Blending and Shipping Plant No. 1 Lead Line**

**T. Lizarraga**

## BACKGROUND

The subject 4-inch, A-53 carbon steel, schedule standard, aviation fuel gas transfer line (or 1 Lead Line) has sustained corrosion damage at several locations over its length. The corrosion is primarily external, however a Plant inspection report, dated 27 March 2003, also notes local areas of internal corrosion.

On 20 August Chevron ETC was contacted to participate with Plant staff in completing a walkdown inspection of the entire line. The objective of the inspection was to review the previously documented locations of corrosion damage and visually determine the most severe metal loss location. Subsequently non-destructive examination (NDE) was completed to determine the through-thickness condition of the pipe at the location of most severe external corrosion damage.

The Plant advised that the 1 Lead Line was shutdown and would not return to service prior to completion of qualified welded and/or mechanical clamp (encapsulation) repairs. In the interim the Plant requested that a pressure boundary integrity assessment of the limiting corrosion damaged area be completed to quantitatively establish its former in-service failure threshold.

**Analysis**

Based on ASME B31.3 piping code stipulated visual (VT) and radiographic (RT) inspection techniques, both ETC and Plant staff (K. Gish) concurred that the limiting locally corroded region of the 1 Lead Line would be fully bounded, on minimum thickness, by an idealized uniform 0.1 inch remaining pipe wall thickness, with the inclusion of a local pit having a 0.25 inch diameter and a depth of 0.05 inches, as compared to the nominal new condition of 0.237 inches wall thickness.

The transfer line material is ASTM A-53 carbon steel and it was conservatively assumed to have the lowest strength[1] properties as defined by the Grade A specification. Specifically, the material yield strength, at ambient and low temperatures (200 $^oF$), is 30 ksi, the ultimate strength is 48 ksi and the ASME B31.3 code membrane allowable stress is 16 ksi. The piping pressure induced hoop stress is governed by a membrane stress state, and thereby the stated allowable stress is utilized by the design code to establish the minimum required pipe wall thickness.

The location of the reported worst corrosion damage is near a deadweight pipe support. Field assessment[2] of the support and adjacent spans concluded that supplemental loading due to deadweight bending could be taken as negligible. The line operates essentially at ambient, so no meaningful thermal component of loading is developed.

Given the above simplified geometry and pressure-dominated loading basis, the described idealized defect can be evaluated by various closed-form strength, or rupture, evaluation procedures widely used in the industry for both process piping and pipeline applications. Table 1 tabulates these results and the detailed worksheets[3] are attached in Appendix 1.

In Table 1 note that the NG-18 method is a determination basis for a leaking, or weeping, failure versus a catastrophic failure condition. In this case the pit has very low surface area, and a 50 percent depth relative to the surrounding pipe wall thickness. So intuitively the global failure result of NG-18 is sensible. Specifically, the 50 percent local pipe wall defect depth does not affect the global failure strength since its 0.049 square inch area is insufficient to locally reduce the apparent strength of the surrounding (thicker) pipe wall section.

Recognize that the NG-18 method is a discrete evaluation given the material conditions applied. The observed field condition is pitting corrosion where damage (material wastage) is highly biased on the bottom of the pit. Thus the eventual probable failure mode[4] would be continued

[1] Recall that the code strength values are statistical lower bound values determined from numerous mill heats of the designated material specification.
[2] Per Jaan Taagepera, PE, ETC Senior Engineer, Engineering Analysis Group, who completed the walkdown inspection with Plant staff. Note also that the line is grade-mounted and thus no amplified in-structure seismic loading is applicable.
[3] Acknowledgment to CP Hsiao who programmed the MathCad worksheets.
[4] The NG-18 method was parametrically applied using progressively deeper pitting corrosion with a leak failure mode being predicted. The gross failure case is not deemed credible in light of the margin of three (3) safety factor.

corrosion in the pit resulting in a pin-hole breach of the remaining pit ligament, with consequent leaking. However, the surrounding corroded wall thickness (conservatively approximated as 0.1 inches thickness) would easily sustain the internal pressure loading stably after the pit breach.

The pit and corroded area combination failure capacity results of Table 1 clearly show that no threat of catastrophic failure existed from the as-found corrosion damage condition. All failure pressure magnitudes are commensurate with the approximate three (3) safety factor of the original ASME B31.3 piping design code. Specifically, the line maximum operating pressure is 250 psi and thus the margin against failure is greater than a factor of three (3). Note that the Kastner Method is limiting (i.e the lowest predicted failure pressure).

**Table 1 Failure Pressure Predictions for a Pit Isolated in a Thinned Pipe Section**

| Method | Failure Pressure (psi) | Failure Mode |
|---|---|---|
| ASME B31.G | 810 | NA |
| RSTRENG (Modified B31.G) | 978 | |
| DNV RP-F101 | 1213 | |
| Shell-92 | 1059 | |
| PCORRC | 1142 | |
| Kastner's Method | 757 | |
| NG-18 | NA | Global / No Pit Failure |

Although the failure pressure threshold of the analyzed defect is high the Plant decision to repair the line prior to a return to service is correct. Note that irrespective of analytical results, the various defect assessment codes, such as ASME-API-579 and B31.G, include guidance to repair metal loss defects below specified limits. ASME-API-579 stipulates 0.1 inches, while ASME B31.G uses a limit of 20 percent of the nominal pipe wall schedule thickness (i.e. 0.047 inches, as compared to a remaining thickness of 0.05 inches in this Blending and Shipping Plant case).

These limits are recommended primarily to assure ruggedness against external hazards such as stepping loads, impact due to dropped tools and other industrial hazards. In this case, the 0.25 inch diameter target area of the controlling exposed pit is so small that direct impact from such hazards is physically improbable.

Recognize that discovery of such metal loss defects, during operation, which are below recommended threshold limits may optionally be evaluated for short-term service integrity by detailed stress analysis methods. This is provided to allow reasonable time for staging of repair materials and craft.

D. M. Bosi – Chevron ETC

Please call me if you have any questions or concerns.

**D. M. Bosi, P. E,**
**State of California**
Staff Consulting Engineer

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Richmond Electronic Repository
MEEDOCS

# Appendix 1

## MathCad Failure Pressure Worksheets

**(5 sheets follow)**

# Local Metal Loss Assessment

| | | |
|---|---|---|
| $D := 4.226 \cdot in$ | | outside diameter, 4.5 - 2x(0.137) = 4.226 |
| $t := 0.1 \cdot in$ | | current thickness |
| $SMYS := 30000 \cdot psi$ | | |
| $SMTS := 48000 \cdot psi$ | | |
| $F := 0.533$ | | design factor, make allowable stress = 16 ksi |
| $d := 0.50 \cdot t$ | $d = 0.05 in$ | metal loss depth |
| $L := 0.25 \cdot in$ | | metal loss length (longitudinal) |
| $w := 0.25 \cdot in$ | | metal loss width (circumferential) |

## The original B31G Method

$\sigma 1 := 1.1 \cdot SMYS$ $\qquad$ $\sigma 1 = 3.3 \times 10^{4}\ psi$

$P0 := \frac{2 \cdot t \cdot \sigma 1 \cdot F}{D}$ $\qquad$ $P0 = 832.418\ psi$

$\frac{d}{t} = 0.5$

$A := \frac{0.893 L}{\sqrt{D \cdot t}}$ $\qquad$ $A = 0.343$

$Mt := \sqrt{1 + A^2}$ $\qquad$ $Mt = 1.057$

For d/t <= 0.8 and A <= 4

$Rs1 := \frac{1 - \frac{2}{3} \cdot \frac{d}{t}}{1 - \frac{2}{3} \cdot \frac{d}{t} \cdot \frac{1}{Mt}}$ $\qquad$ $Rs1 = 0.974$

For d/t <= 0.8 and L/sqrt(Dt) > 4

$Rs2 := 1 - \frac{d}{t}$ $\qquad$ $Rs2 = 0.5$

$Rs := if(A \le 4, Rs1, Rs2)$ $\qquad$ $Rs = 0.974$

Failure pressure

$Pf := P0 \cdot Rs$ $\qquad$ $Pf = 810.448\ psi$

## The Modified B31G (RSTRENG 0.85dL) Method

$\sigma 1 := SMYS + 10000 \cdot psi$ $\quad\quad \sigma 1 = 4 \times 10^{4}\ psi$

$P0 := \dfrac{2 \cdot t \cdot \sigma 1 \cdot F}{D}$ $\quad\quad P0 = 1.009 \times 10^{3}\ psi$

$\dfrac{d}{t} = 0.5$

$A := \dfrac{L^{2}}{D \cdot t}$ $\quad\quad A = 0.148$

For L^2/(Dt) <= 50

$Mt1 := \sqrt{1 + 0.6275 \cdot A - 0.003375 \cdot A^{2}}$ $\quad\quad Mt1 = 1.045$

For L^2/(Dt) > 50

$Mt2 := 0.032 \cdot A + 3.3$ $\quad\quad Mt2 = 3.305$

For d/t <= 0.8 and L^2/(Dt) <= 50

$Rs1 := \dfrac{1 - 0.85 \cdot \dfrac{d}{t}}{1 - 0.85 \cdot \dfrac{d}{t} \cdot \dfrac{1}{Mt1}}$ $\quad\quad Rs1 = 0.969$

For d/t <= 0.8 and L^2/(Dt) > 50

$Rs2 := \dfrac{1 - 0.85 \cdot \dfrac{d}{t}}{1 - 0.85 \cdot \dfrac{d}{t} \cdot \dfrac{1}{Mt2}}$ $\quad\quad Rs2 = 0.66$

$Rs := if(A \le 4, Rs1, Rs2)$ $\quad\quad Rs = 0.969$

Failure pressure

$Pf := P0 \cdot Rs$ $\quad\quad Pf = 977.652\ psi$

**Advantica LPC-1 Method - same as DNV RP-F101**

$\sigma 1 := SMTS$ $\sigma 1 = 4.8 \times 10^4 psi$

$P0 := \frac{2 \cdot t \cdot \sigma 1 \cdot F}{D - t}$ $P0 = 1.24 \times 10^3 psi$

$\frac{d}{t} = 0.5$

$A := \frac{L^2}{D \cdot t}$ $A = 0.148$

$Q := \sqrt{1 + 0.31 \cdot A}$ $Q = 1.023$

For d/t <= 0.85

$Rs := \frac{1 - \frac{d}{t}}{1 - \frac{d}{t} \cdot \frac{1}{Q}}$ $Rs = 0.978$

Failure pressure

$Pf := P0 \cdot Rs$ $Pf = 1.213 \times 10^3 psi$

**Shell-92 Method**

$\sigma 1 := 0.9SMTS$ $\sigma 1 = 4.32 \times 10^4 psi$

$P0 := \frac{2 \cdot t \cdot \sigma 1 \cdot F}{D - t}$ $P0 = 1.116 \times 10^3 psi$

$\frac{d}{t} = 0.5$

For d/t <= 0.8

$Rs := \frac{1 - \frac{d}{t}}{1 - \frac{d}{t} \cdot \frac{1}{\sqrt{1 + 0.8 \cdot \left(\frac{L}{\sqrt{D \cdot t}}\right)^2}}}$ $Rs = 0.948$

Failure pressure

$Pf := P0 \cdot Rs$ $Pf = 1.059 \times 10^3 psi$

**PCORRC Method**

$\sigma 1 := SMTS$ $\sigma 1 = 4.8 \times 10^{4}\ psi$

$P0 := \frac{2 \cdot t \cdot \sigma 1 \cdot F}{D}$ $P0 = 1.211 \times 10^{3}\ psi$

$\frac{d}{t} = 0.5$

$Rs := 1 - \left(\frac{d}{t}\right) \cdot \left[ 1 - e^{-0.222 \cdot \left(\frac{L}{\sqrt{D \cdot t}}\right) \cdot \frac{1}{\sqrt{1 - \frac{d}{t}}}} \right]$ $Rs = 0.943$

Failure pressure

$Pf := P0 \cdot Rs$ $Pf = 1.142 \times 10^{3}\ psi$

**Kastner Method (for assessing circumferential extent of the metal loss)**

$\beta := \frac{w}{D}$ $\beta = 0.059$

$\eta := 1 - \frac{d}{t}$ $\eta = 0.5$

$\sigma 1 := \frac{SMYS + SMTS}{2}$ $\sigma 1 = 3.9 \times 10^{4}\ psi$

For d/t <= 0.8

$\sigma f := \frac{\eta \cdot [\pi - \beta \cdot (1 - \eta)]}{\eta \cdot \pi + 2 \cdot (1 - \eta) \cdot \sin(\beta)} \cdot \sigma 1 \cdot F$ $\sigma f = 1.984 \times 10^{4}\ psi$

$\sigma\_axial := 0.5 \cdot SMYS \cdot F$ $\sigma\_axial = 7.995 \times 10^{3}\ psi$

σf should be greater than σ_axial to be safe

$Pf := \frac{4 \cdot t \cdot \sigma f}{D}$ $Pf = 1.878 \times 10^{3}\ psi$

$MAOP := \frac{2 \cdot t \cdot SMYS \cdot F}{D}$ $MAOP = 756.744\ psi$

**NG-18 Equations**

$\sigma 1 := SMYS + 10000 \cdot psi$ $\qquad \sigma 1 = 4 \times 10^4\ psi$

$\frac{d}{t} = 0.5$

$\Lambda := \frac{L^2}{D \cdot t}$ $\qquad \Lambda = 0.148$

$Mt := \sqrt{1 + 0.6275 \cdot \Lambda - 0.003375 \cdot \Lambda^2}$ $\qquad Mt = 1.045$

Part-Wall Equation

$\sigma f\_p := F \cdot \sigma 1 \cdot \frac{1 - \frac{d}{t}}{1 - \frac{d}{t} \cdot \frac{1}{Mt}}$ $\qquad \sigma f\_p = 2.043 \times 10^4\ psi$

Through-Wall Equatio

$\sigma f\_t := F \cdot \frac{\sigma 1}{Mt}$ $\qquad \sigma f\_t = 2.04 \times 10^4\ psi$

Mode := if(σf_p < σf_t, "Leak", "Rupture") Mode = "Rupture"